NATIONAL BUREAU OF STANDARDS :: U.S. DEPARTMENT OF COMMERCE

NBS

"... the very highest and best."

"It is not sufficient to have fairly good standards of measurements, fairly good methods of testing materials, mechanisms, or structures, or reasonably good determinations of important physical constants. The standards, the measurements, the test procedures must be the very best, the most accurate, the most reliable that can possibly be achieved at any given time, limited only by the state of the art at the time. It is thus more than a play on words to say that the 'standards' by which the Bureau is judged must be the very highest and best."

Report of a 1953 Committee which evaluated the Bureau's functions and responsibilities.

THE NATIONAL BUREAU OF STANDARDS

1966

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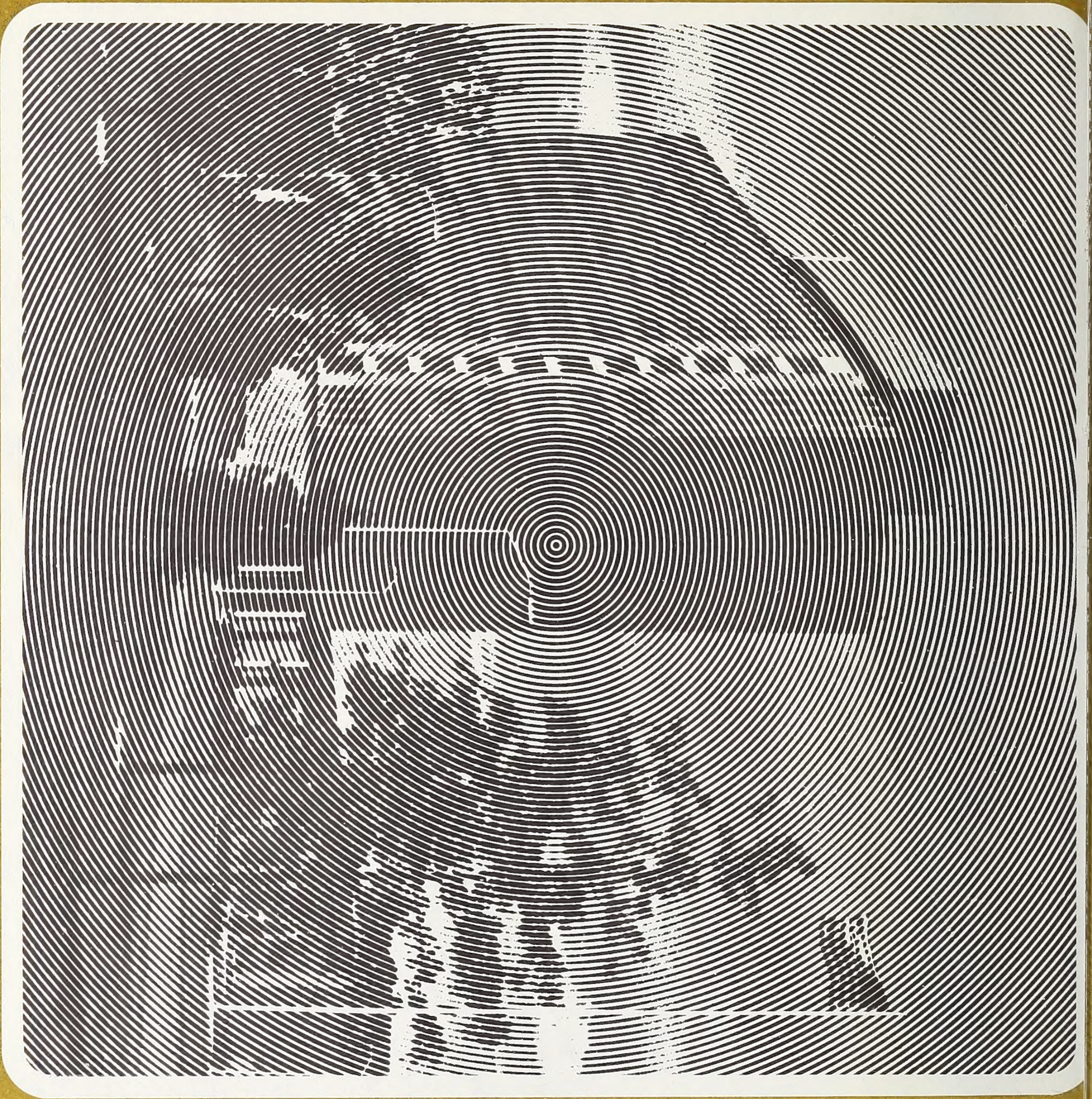


A MAJOR SCIENTIFIC RESOURCE

As the Nation's central measurement standards laboratory, NBS covers the entire spectrum of the physical sciences and engineering. Its competence in many fields is recognized and respected the world over.

This recognition and respect, gained through its scientific contributions over many years, are an invaluable aid to NBS in providing national leadership in the measurement and related sciences. NBS does so despite the fact that it has no power to enforce the measurement standards developed, for this country's measurement system is a voluntary one, based on mutual cooperation among the various levels of Government, industry and other private interests, and the average citizen.

Leadership of such a voluntary system is based on the quality of work done and the reputation earned; these are the fruits of the extensive program of basic research at NBS in support of its mission.

Moreover, in order for NBS to provide services vital to science, industry, and government—such as measurement units and techniques, standard test methods, calibration and testing, critically evaluated data, reference materials, etc.—a scientific competence adequate to the national needs must be maintained.

By mission and nature, NBS works at the frontiers of science and its application to technology.

MAJOR PROGRAMS

BASIC MEASUREMENT STANDARDS

- Develop standards and techniques for consistent measurements,
- Determine what measurements are meaningful,
- Find means to evaluate measurements and measurement techniques,
- Determine major physical constants.

ENGINEERING MEASUREMENTS AND STANDARDS

- Formulate criteria for the quantitative evaluation of commercial products and services,
- Develop standards and techniques for measuring the properties and performance of systems, including manufactured articles,
- Provide the means for measuring the cost-benefit relationships in large and complex systems, such as government operations, urban transportation.

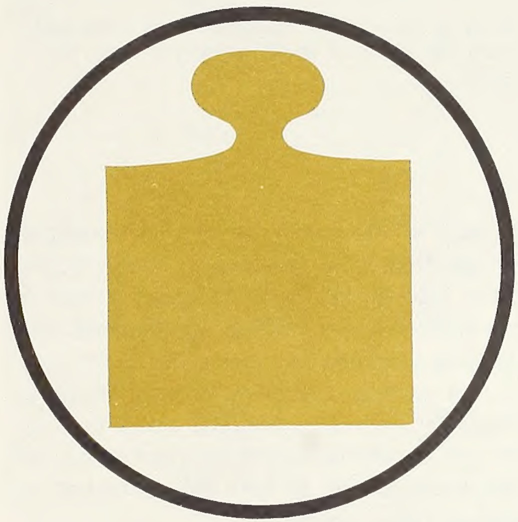
PROPERTIES OF MATTER AND MATERIALS

- Generate urgently needed data of high precision on the physical and chemical properties of matter and materials, including the effects of environment,
- Collect, critically evaluate and disseminate selected existing data,
- Study the relationship between the properties of materials and their composition and structure.

TECHNICAL ASSISTANCE

- To industry, through technical information, research associate programs, and spurs to invention and innovation,
- To Government, to solve technical problems, plan programs, and improve operational effectiveness.

The International Standard of Length is a wavelength of orange-red light produced by the gas krypton.



THE BASIC FOUR

NBS is the keeper of our national measurement standards. NBS must establish standards for the many units used to measure; improve these standards to cover the required range of values and to the necessary accuracy; develop methods for giving everyone direct or indirect access to the national standards. By doing this job, NBS keeps the country's measurements accurate, uniform, compatible, and reliable.

Man derives almost all of his measuring units—for electricity, radiation, heat, physical or chemical properties, electronic and radio quantities—from four basic ones:

- MASS
- LENGTH
- TIME
- TEMPERATURE

Our national standard for mass measurements is a metal cylinder weighing one kilogram. Mass measurements can be made with an accuracy of one part in a hundred million.

Our standard for length measurements is a wavelength of light given off by the gas krypton. Using a complex system of mirrors and lenses, scientists count the number of wavelengths of light between one point and another, and are able to measure to an accuracy of almost a part in 100 million.

For many centuries, man's standard for measuring time has been the apparent movement of heavenly bodies. In 1964, however, the world adopted a provisional definition of the second as 9,192,631,770 oscillations of the cesium atom, and the world moved onto atomic time. The measurement of atomic time is among the most accurate measurements man makes—with an accuracy of a few parts in 1 trillion in a day—equivalent to one second in 30,000 years.

The reference point for temperature measurement is the triple point of water. This is where water exists as ice, liquid, and vapor, all at the same time. The triple point temperature is 0.01 degree C. Temperature measurements in this range can be made with an accuracy of a part in a million.

DERIVED STANDARDS

From the four basic standards, NBS develops the measurement standards for many other units. For example, NBS scientists derive a unit for measuring electrical current by measuring the magnetic attraction between two coils of wire carrying a current. From the dimensions of the coils (measured in terms of length) and the strength of the pull between them (measured in terms of mass) they establish a value for the amount of current flowing.

In this measurement, an important factor is the pull of the earth's gravity on the weights used, and so NBS scientists must know the acceleration of gravity to a high degree of accuracy.

In addition to measuring such phenomena as gravity, NBS scientists also measure physical constants—the speed of light for example—as part of their regular program.

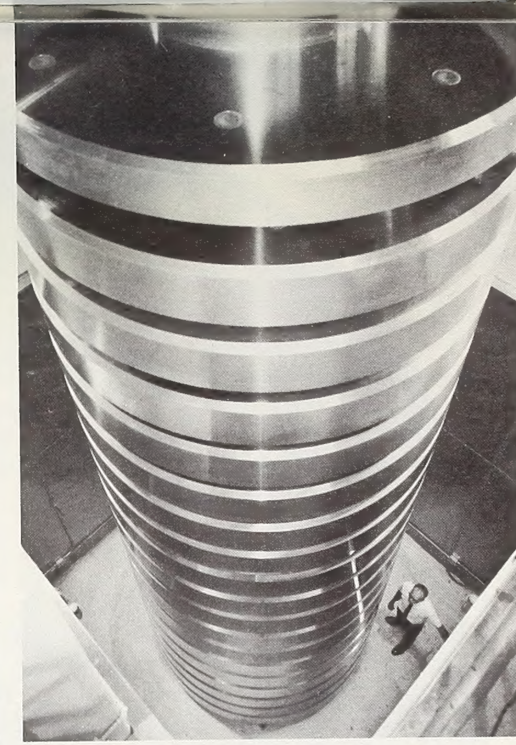
EXTENDING THE RANGE OF MEASUREMENTS

Not all measurements are made at the exact quantity defined by the national standards. While the national standard of mass is a one-kilogram weight, things of all sizes are weighed—from tiny quantities of prescription drugs to loaded freight cars. Though the national standard of length is the meter, man must be able to measure the diameter of an atom or the distance to the moon. To make these and other measurements possible, NBS works out ways of measuring multiples and fractions of the basic units for each type of measurement. And throughout this multiplication and division process, NBS must maintain the highest possible degree of accuracy. For example, its million-pound deadweight machine, which checks the accuracy of force-measuring devices such as are used to measure the thrust of large rockets, includes a stack of fifty-thousand-pound weights, each accurate to a few ounces. And each of those great weights is directly descended from the national standard of mass—the kilogram.

IMPROVING THE ACCURACY OF THE STANDARDS

No measurement is ever perfect. One of the main tasks of NBS, however, is to get as close to perfection as possible. Improvement in the accuracy of measurements is the key to scientific and industrial progress: inadequate accuracy can mean fitting parts by costly trial and error and it can mean expensive overdesigning. Improvements of measurement capability, on the other hand, can mean new scientific discoveries, more efficient industrial operations, new and improved products.

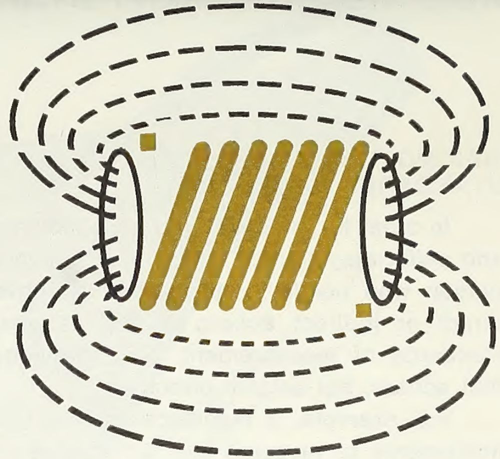
This work can be trying and seemingly endless—a technical wonderland in which you must run as fast as you can in order to stay in the same place. For example, though NBS can operate its latest atomic clock with an accuracy of about a part in one trillion, some modern applications, like tracking satellites and timing the disintegration of nuclear particles, develop requirements for perhaps a hundred times that accuracy. Experimental atomic clocks now under development at NBS are designed to answer these needs.

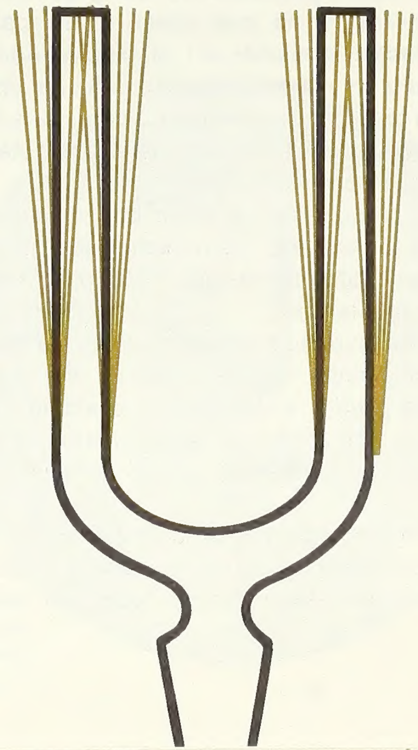


Each of these 50,000 pound weights is derived from the National standard of mass, the kilogram.

MAJOR DERIVED STANDARDS

GROUP	QUANTITY	UNIT
SI Basic	length	meter
	mass	kilogram
	time	second
	temperature	degree Kelvin
	electric current	ampere
	luminous intensity	candela
Electrical and Magnetic	resistance	ohm
	capacitance	farad
	inductance	henry
	voltage	volt
	power	watt
	energy	watt-hour
	frequency	hertz
	magnetic flux	weber
	magnetic flux density	tesla
	magnetizing force	ampere
	noise, radio frequency	watt/hertz
	field strength, radio frequency	volt/meter
	phase shift, radio frequency	degree
	attenuation, radio frequency	decibel
	reflection coefficient, radio frequency	watt/watt
	time delay	second
	impulse spectral density	watt/hertz
Mechanical	acceleration	
	linear	meter/sec^2
	angular	rad/sec^2
	angle, plane	radian
	flow	
	(air)	scfm
	(water)	meter^3/sec
	(fuels)	kilogram/sec
	force	kilogram
	humidity	gram/kilogram
	pressure	bar
	sound	volt/cm^2/dyne
	vacuum	millibar
	velocity	meter/sec
	wind speed	
	vibration	
	displacement	millimeter
	velocity	meter/sec
	acceleration	meter/sec^2
	volume	meter^3
	liquid	
Optical Radiation	color temperature	degree Kelvin
	chromaticity coord.	———
	luminance	candela/cm^2
	luminous flux	lumen
	irradiance	watt/cm^2
	spectral	watt/cm^2-nm
	radiance	watt/steradian-cm^2
	spectral	watt/sr-cm^2-nm
	wavelength	nanometers
	ultraviolet	
	visible	
	infrared	
Ionizing Radiation	electron beam current	ampere
	neutron emission rate	count/sec
	neutron flux density	count/cm^2
	radioactivity	curie
	x-ray beam energy	microwatt/cm^2
	x-ray & x-ray exposure	roentgen
	x-ray spectra	count/MeV





MAKING THE STANDARDS AVAILABLE

In order for the country to have a single and uniform system of measurement, every person who needs to measure must have direct or indirect access to the national standards of measurement. NBS provides that access, but seldom directly.

For example, a manufacturer will use instruments to measure the dimensions of parts on his production line. To make sure the instrument is reading correctly, he will probably check it with gage blocks—metal blocks made to very precise dimensions. To make sure the production-line gage blocks are accurate, he may check them against the factory's master set of blocks. And to be sure his master set is accurate, he sends them to NBS for calibration. There, for a fee, NBS compares them with the national standard of length.

Through such a chain of comparisons every measuring instrument used in the United States is related to the appropriate national standard.

Measurement standards may be made independently reproducible, as the wavelength length standard, for example. The worker can then use the standard directly in his own laboratory and do his own calibrations.

One of the main anchor points for the measurement system is the set of physical constants determined by NBS. An accurately measured physical constant — the speed of light, for example—can be used by

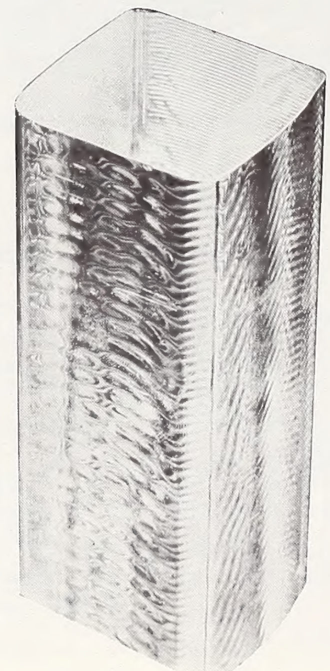
186,282

MILES PER SECOND

many workers to compare measurement units and measurement procedures, and to check measuring instrumentation.

A closely related way of distributing measurement standards is in the form of data on properties of materials. When NBS measures the melting point of some material—benzoic acid, for example—it publishes the number and anyone can check his own thermometer by dipping it in melting benzoic acid. To be certain the benzoic acid he is using is pure and reliable, the measurer may buy from NBS a standard reference material—a sample of ultra-pure benzoic acid sealed in a glass cell. Thus, standard reference materials are packaged data that serve to distribute measurement standards, and give industry a basis for assaying raw materials, controlling production processes and quality, and evaluating finished products.

Standard materials, like this one for glass viscosity, are used to check measuring instruments.



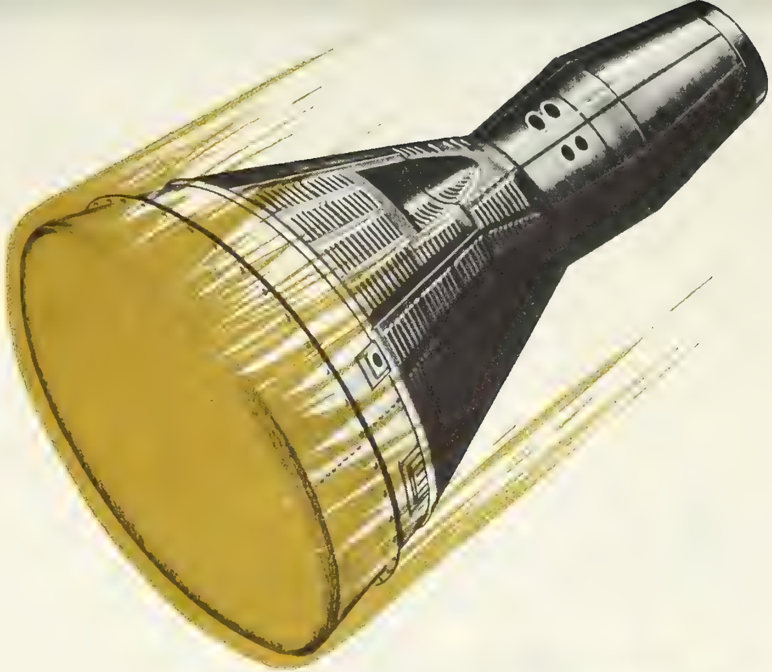
INSURING MEANINGFUL MEASUREMENTS

The fact that a measurement produces a number does not guarantee that the measurement is a good one. Many problems may keep you from getting a good, reliable, usable number. One of these is inaccuracy of the instruments, and this is what the entire instrumentation and calibration effort of the National Bureau of Standards is designed to minimize.

To make sure measurements are meaningful, we must first decide *what* we want to measure, and then be sure we are measuring *that* and not something else.

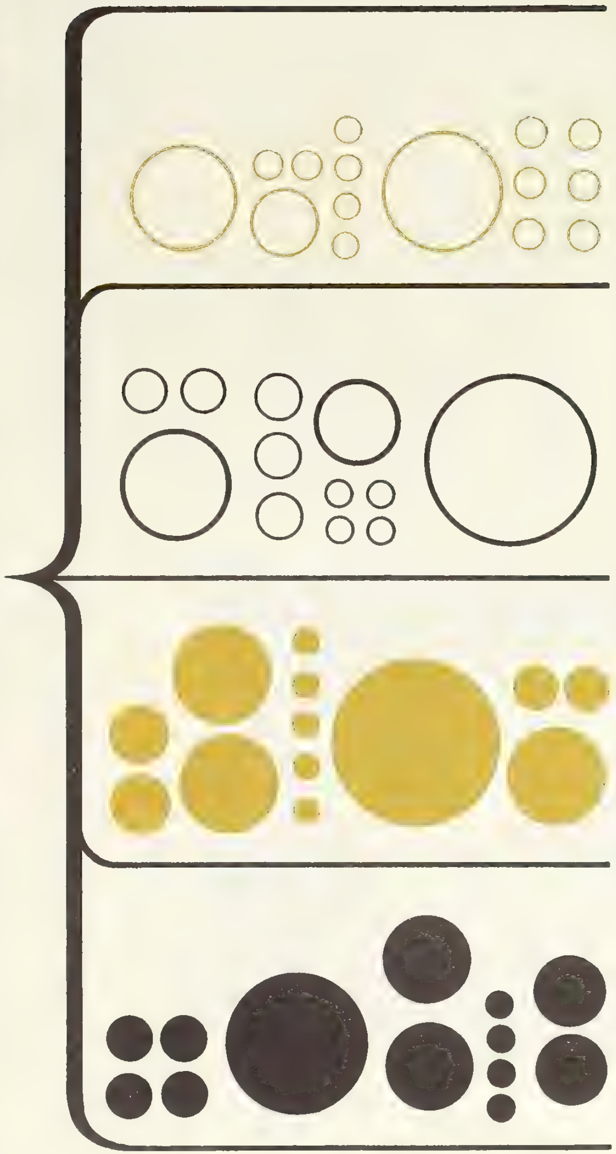
This is especially true on the production line, where conditions cannot be controlled as closely as in the laboratory. As environments change, and as our understanding of the properties of matter and materials improves, so does the identification of what is meaningful to measure. For example, measurement of extremely high temperatures is now meaningful in nuclear reaction or satellite re-entry problems. Measurement of incredibly small concentrations of impurities in materials is meaningful and necessary in the design of transistors.

NBS does much research and publishes much information on *what* to measure, *how* to measure and how to measure how well you've measured.



To find out how a ceramic will hold up at high temperatures, it is most meaningful to measure its behavior directly under those conditions.

PROPERTIES OF MATTER AND MATERIALS



A DATA BANK FOR SCIENCE AND ENGINEERING

Scientific and technical data are numbers describing the characteristics and properties of matter and materials. Characterization tells what a material is—its composition and structure. Properties tell how a material will behave and interact with its environment.

The primary output of NBS research is scientific and technical data. Indeed, NBS is a key "data bank" used extensively by scientists and engineers throughout the United States in their daily work. The data are used in essentially two ways—to calibrate measurement systems, and to support research and development. The latter enables scientists and engineers to predict whether a proposed component or system is feasible and then to design the parts to do the job.

In addition to the data developed at NBS, its Office of Standard Reference Data collects, selects, evaluates and disseminates existing data wherever they originate. This program is part of the National Standard Reference Data System, the operation of which is an NBS responsibility.

Standard reference data are carefully selected and collected from the millions of pages of scientific literature in which they appear. They are then critically evaluated for accuracy and reliability, compiled in handbooks and tables, and made available to the scientists and engineers who need carefully evaluated data in their everyday work.

The purpose of the National Standard Reference Data System is to coordinate data evaluation and compilation activities in the United States and couple them effectively with international data programs.

In carrying out the two parts of the numerical data program, generation of new data and dissemination of existing data, NBS continually surveys the Nation's needs for data. It stimulates work in the scientific and technical community to meet identified needs, and performs in its own laboratories research, not being done elsewhere, in areas of importance to science and industry. NBS also ensures the compatibility of data with measurement units used throughout the world.

A WIDE RANGE OF RESEARCH

Our scientific, technical, and industrial progress is primarily materials limited. That is, we can go only so far before we discover we must improve our materials or create new ones. Thus there are hundreds of thousands of man-made compounds which span the range from synthetic drugs to fabrics.

In many areas even the process of measurement is materials-limited. For example, as now performed, the measurement of length on the production line can be no more accurate than the gage blocks used to check those measurements. The stability and reliability of the blocks depend on the properties of the material from which they were made.

Our expanding technology demands better materials, and the key to improvements is a thorough understanding of the properties of existing materials.

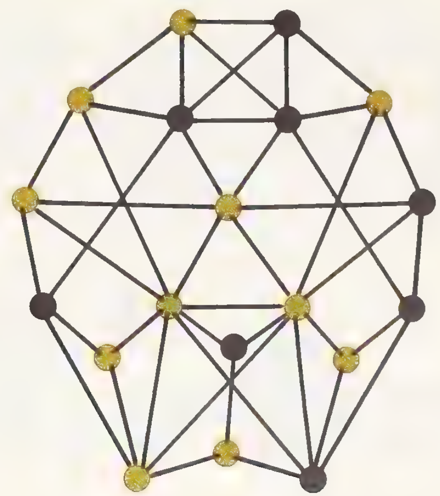
NBS research on properties of matter and materials rests on a wide base—ranging from fundamental particles to bulk materials, from inorganic to organic chemistry, from cryogenic to plasma temperatures.

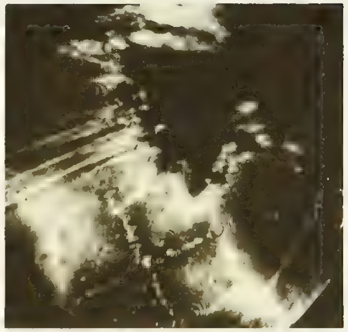
We can characterize a particular atomic nucleus by its size, shape, and component parts—that is, determine its composition and structure. This knowledge enables us to understand the ability of the nucleus to capture neutrons. We can characterize a full atom by the number of electrons and their energy levels, and thus can interpret the light given off by the atom. From characterizing the size, structure, and shape of a complex polymer molecule, we can develop some understanding of the physical properties of the plastic—its hardness, resistance to heat, and so on.

In addition to studies of nuclei, atoms, and molecules, NBS does research on the bulk properties of materials, such as a piece of steel, a crystal of silicon, or whatever. Bulk properties include thermal conductivity, viscosity, melting point, etc.

Preparation and characterization of research reference materials are an essential part of a materials research program. Samples of these materials, once prepared and characterized, with relevant properties identified, serve as benchmarks for NBS and outside scientists in their materials research.

A new research material is not always the greatest dividend from research on preparation and characterization. New preparation techniques and measurement methods are often even more valuable to industry and the scientific community. This is because advances in materials technology often lead to advances in basic science. For example, the ability to prepare and characterize samples of germanium and silicon sparked the current electronics revolution, which in part made possible the development of modern data processing, and led to major progress in solid-state physics. Similarly, the preparation of nylon greatly stimulated polymers research and fostered the birth of many new industries.





Materials problems like corrosion can be solved only by a fundamental understanding of the processes involved. Clean iridium metal (top) is damaged by corrosion (dark areas–middle photo). Field-ion micrographs with a magnification of one million times show the shadows of individual atoms.

Studies of the behavior of materials in their environment (below) yield keys to solving such environmental problems as corrosion.

Slush hydrogen, a semi-solid form developed at NBS, should be a more compact way of carrying this important space fuel.

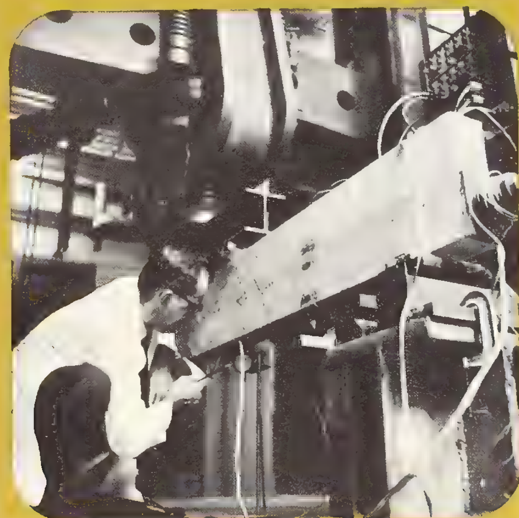
1. *Measurement of the effectiveness of a fire extinguishing agent can mean more effective fire-fighting methods.*
2. *Measurement of the threshold of human hearing by bone conduction requires active participation by the scientist.*

1.

2.

3. *New fields require new measurement techniques. Here transistors are mounted to measure their performance.*
4. *Methods must be developed to measure the performance of structural members like concrete beams.*

3.



4.

5. *NBS aided industry experts and State weights and measures officials in developing a method for measuring contents of aerosol products.*
6. *Even the uniformity of the thin coating on a piece of electroplated metal is within the measuring ability of modern technology.*

5.

6.

ENGINEERING MEASUREMENTS AND STANDARDS

A RAPIDLY EXPANDING FIELD

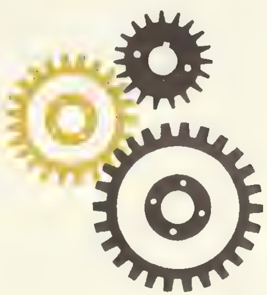
Measurement of the length of an object is a fairly straightforward task. Measurement of its density is slightly more complex, and measurement of its chemical purity or the average size of its molecules yet more complex.

As products become more sophisticated and complex, so do the measurements. For example, in dealing with solid-state materials used in transistors, it is necessary not only to make the ordinary measurements of the properties of such materials, but also to determine the way they function in an electronic circuit. NBS now works on methods for measuring and specifying the characteristics of complete electronic circuits and subassemblies, and looks toward measurements of the performance of entire electronic computers. And beyond these measurements are such things as the measurement of the characteristics and behavior of entire systems—such as the transportation system or the patent system, etc.

Measurement of the characteristics of such systems is an unfamiliar idea. Yet such measurement is analogous to the more familiar one of measuring a gear wheel. A single measurement or number is not sufficient to describe the gear. There are dimensions in various directions, the angles and curvature of many of its contours, even the smoothness of its finish. The result is a set of numbers which describe the gear to the extent needed. A direct extension of this concept leads to measurements which give a set of numbers describing a computer or a transportation system. And these numbers serve the same purposes as any measurements; they form a basis for informed decision and action, and as such facilitate the selection and exchange of goods in commerce.

An added consideration is the fact that in systems measurements—such as those for a transportation system, or the cost-benefit relationships of various Government and industry activities—measurements of human reactions, social and economic considerations, and other intangible factors must somehow be part of the total measurement.

This is the concept of a new kind of engineering, one that has been applied to military and space problems, but not, as yet, widely used in other applications. NBS seeks to expand the use of engineering measurement techniques into new fields to provide more rational quantitative approaches to problems.



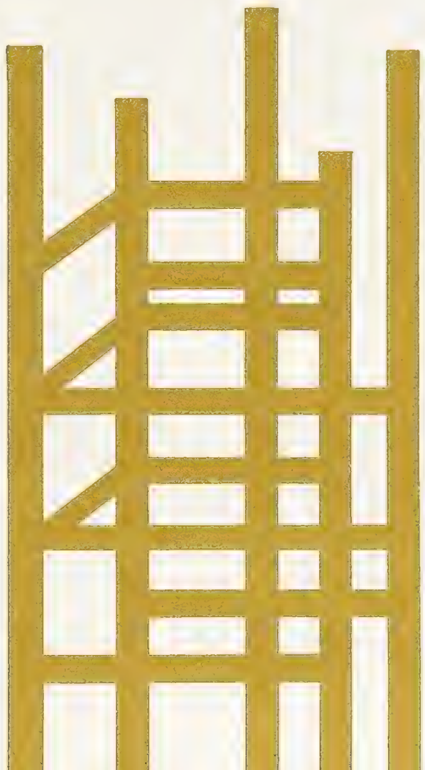
PERFORMANCE CRITERIA

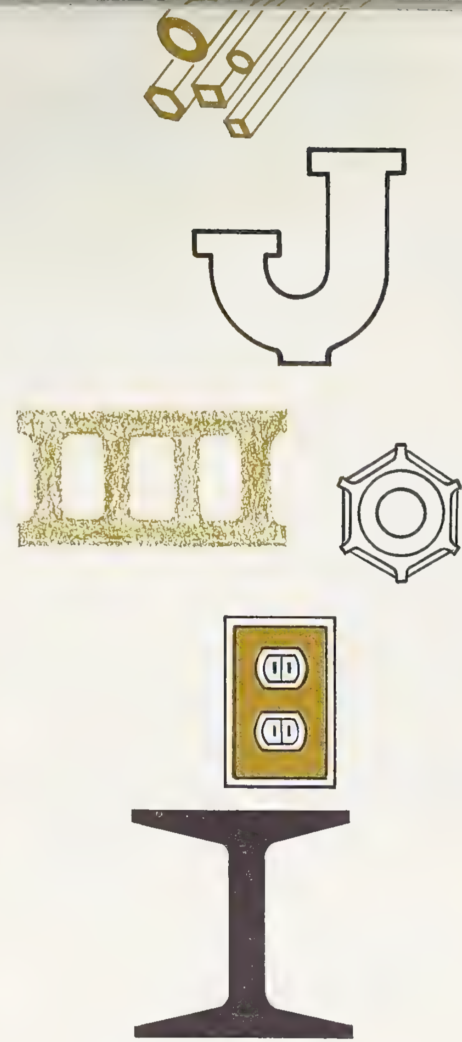
With the measurement standards and techniques provided by NBS for measuring complex structures and devices, industry develops performance standards to evaluate the functioning of products. Performance criteria state the function that an element or system must perform.

Performance criteria based on function are vital to innovation in industry. When a wall is defined in terms of 2 x 4's (a certain size of lumber) 16 inches on center (a special arrangement), then the choice of ways to build the wall is limited. If, however, the definition is stated in performance terms—that is, how much load the structure must bear, how much heat and sound insulation it must provide, etc.—then the wall can be made in any form and of any material which will do the job.

Thus, performance criteria liberate industry from the constraints of traditional materials and traditional procedures. With the job to be done spelled out in meaningful measurements, new and imaginative solutions can be devised and tested.

Performance standards are usually formalized by industry itself. Such voluntary groups as the American Society for Testing and Materials and the United States of America Standards Institute, in cooperation with industry, write codes and specifications for products and industrial processes, often based on the measurement methods developed at NBS. In this sense, NBS plays the role of a technical resource for standard-making groups. Product standards are voluntary agreements among producers, distributors, and users of certain products concerning arbitrary sizes, configurations, and so forth. NBS provides technical support for the development of product standards by industry. Other standards and codes based on NBS test methods and measurement data include building codes, safety codes such as the National Electrical Safety Code and many industrial safety codes.



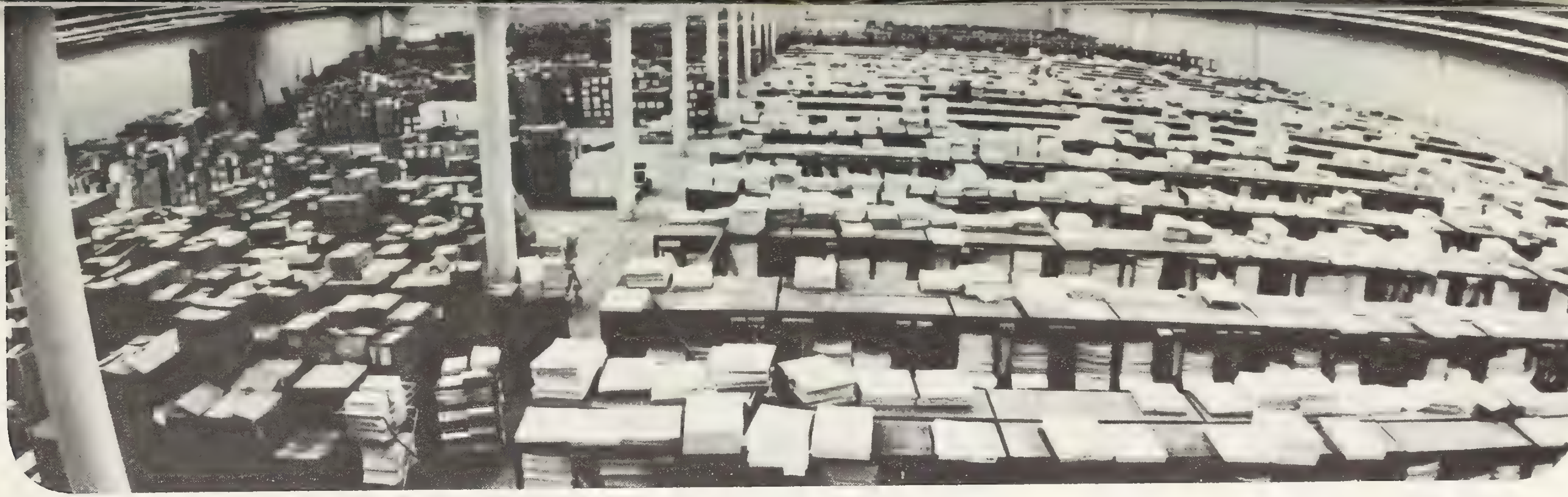


INTERNATIONAL STANDARDS

Foreign markets represent an important potential for American business. Many new and developing countries are in great need of goods and services that can be provided by American industry, and in many established countries there are demands for products that our advanced technology permits us to provide with superior quality and at competitive cost.

A significant deterrent to expanded world trade is the lack of adequate international standards by which to design products and to judge objectively the performance, quality, and general acceptability of goods and services. The need for uniform international standards is as obvious as the need for uniform domestic standards. Today's modern and sophisticated technology depends heavily on compatible and acceptable measurement and performance standards.

NBS, with industry, provides technical people to attend international standardization meetings to represent the American point of view and see that the standards selected and adopted do not unfairly bar U.S. products from foreign markets.



The receiving room at the Clearinghouse for Federal Scientific and Technical Information. The 70,000 research titles processed annually by the Clearinghouse arrive here.

Scientists test a laser geodimeter for making land surveys.

TECHNICAL ASSISTANCE

TO INDUSTRY

Scientific and Technical Information. The highly technical U.S. economy is built on sophisticated scientific and technical knowledge. Because of its mission to promote U.S. economic development through fuller use of science and technology, NBS has become a center for gathering and distributing technical information.

The information developed in the course of NBS's own research and engineering—some of it in specific industrial fields, as in building construction or automatic data processing—is useful to industry and the Bureau maintains its own publication program to keep the public informed.

In addition, NBS is responsible for the dissemination of the unclassified technical information developed in all Federally-sponsored research. Through its Clearinghouse for Federal Scientific and Technical Information, the Bureau gathers, indexes, and publicizes and distributes some 70,000 technical reports per year.

Research Associate Programs. NBS carries on Research Associate Programs in which industry sends scientists and engineers to NBS to work on projects of mutual interest. NBS gets the benefit of the added competence, and industry gets access to the specialized equipment and expertise at NBS.

Invention and Innovation. The Office of Invention and Innovation identifies factors which inhibit or encourage invention and innovation. Among such factors are government patent, anti-trust, tax, tariff, and other policies. The Office provides staff support to the National Inventors' Council, which is concerned with matters relating to invention and innovation.

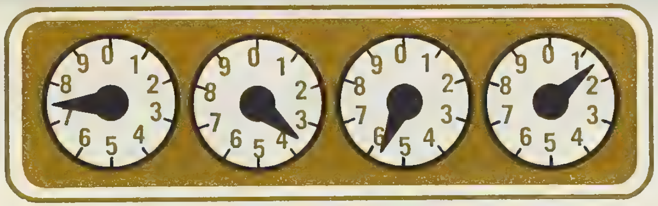
TO GOVERNMENT

NBS is a central technical resource for the entire Government. The Bureau's wide technical competence makes it the choice for a variety of assignments—developing special purpose computer systems, designing automatic floating weather stations, consulting on corrosion problems at Cape Kennedy, helping to establish minimum specifications for Government purchases, etc. Actually, about half of the Bureau's work is financed by funds transferred from other agencies.

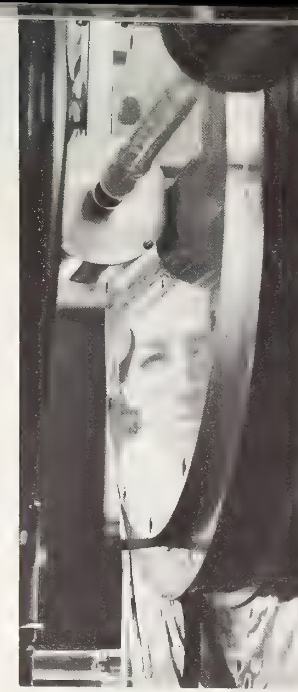
A primary objective of NBS services to other Government agencies is to employ technology in improving the effectiveness of Government operations. For example, the Government is a major user of automatic data processing equipment. To reduce costs and increase efficiency, NBS was assigned the responsibility for advising other agencies on the optimum use of automatic data processing equipment as well as for developing Federal standards for such equipment.

Also in the interest of economy, efficiency, and effectiveness, NBS provides a technical analysis service. NBS develops methods for measuring the cost-benefit relationships of various Government activities. The questions may range from "Of what value is the daily weather report to the average citizen?" to "How do you measure the performance of an entire transportation system?"

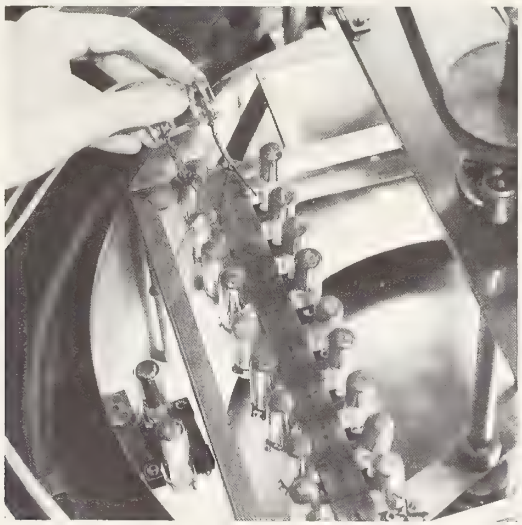
Because of its role as the central scientific resource for the Federal Government, NBS has access to the technical competence of many other governmental agencies. The result is a multiplication of its already considerable resources.



Studies of how materials burn may help improve the safety of buildings and houses.



Measurement of the characteristics of certain atomic species in the laboratory aid the radio astronomer in finding them in outer space.



Upon the standard cells which define the volt rest the electrical measurements of science and industry.

THE AVERAGE CITIZEN

The citizen directly depends on NBS work in many aspects of his daily routine:

Economic—Goods and services are generally exchanged in measured quantities—a pound of butter, a kilowatt hour of electrical energy, etc. All of these measures are based on standards maintained by NBS.

Decision making—Are you going too fast? Should you fill the gas tank? Is it time to leave for the train? And published measurements—the amount of jelly in the jar, the cooling capacity of an air conditioner—help you decide which product or brand to buy.

Health and safety—Much NBS work directly or indirectly protects the citizen's life. Consider the airline pilot surrounded by gages, direction- and range-finding instruments, and so forth. His safety and that of his passengers depend on the reliability of these instruments and their compatibility with those in use on the ground and in other aircraft. NBS work provides the central, national basis for making such measurements compatible and meaningful.

NBS does the technical work and develops the standard for certain mandatory safety stands—those for flammable fabrics, brake fluids, auto seat belts, refrigerator doors.

SCIENCE AND TECHNOLOGY

Perhaps the prime beneficiaries of NBS work are the scientist and engineer. They depend significantly on NBS for measurement standards, and data on the physical constants of nature and the physical and chemical properties of materials.

From the scientists' investigations we gain understanding of the world we live in. Through the engineer's work we control and use the world.

Science—Precise measurements of the properties and behavior of atoms revealed the secrets of atomic energy to us. Precise measurements of the speed of light triggered Einstein's famous theory which has greatly enlarged our understanding of the world around us. The preparation and characterization of such materials as silicon and germanium sparked important advances in solid state physics.

Technology—Probably the space rocket is one of the ultimate measurement problems challenging our technology today. Delicate optical, mechanical, electrical, and chemical systems must work together perfectly. Materials must be selected to perform difficult jobs under violently demanding conditions. To make such selections the engineer depends on data on the characteristics and properties of materials.

Communication—NBS is a major resource to communication among scientists and engineers. The uniformity of the measurement system and the language of units provided by NBS helps technical men to understand each other. Through reliable data produced by research they exchange and evaluate results.

INDUSTRY

Mass production—The key to mass production lies in the use of interchangeable parts. These must be measured accurately in order to fit into the assembly and function properly together.

In producing any complex modern device, a wide range of quantities, physical and chemical, must be measured and coordinated if the device is to be conceived and then to work properly.

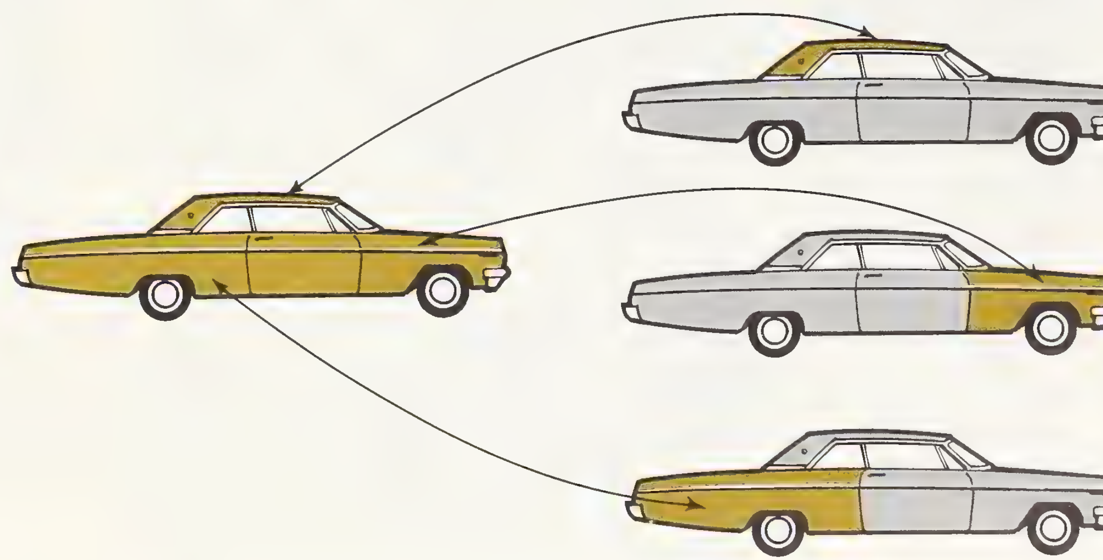
Improved products—Today, a new car can be taken out on the road and run in bursts to its full capabilities immediately. This is because of improved and new materials and improved measurements. Today, parts can be measured more accurately, finished more smoothly, and therefore fit together and work together more smoothly.

Increasingly, new products are emerging from the laboratory. No example could be more vivid than the development of the transistor. These tiny pieces of solid-state material have made possible the ubiquitous portable radios and miniature televisions, more reliable defense and space electronics, and computers which perch on the corner of a desk.

The development of solid state technology to its present level required extremely delicate measurements to determine the electrical behavior of transistor and other materials, to determine the quantities of impurity present, to determine what effect varying the amount of impurity would have on their electrical properties.

New processes—New industrial processes are just as dependent on measurement as new products. For example industry has been using radiation in increasing amounts for a variety of jobs. Radioactive materials and machines which project beams of electrons are used to cure plastics and vulcanize rubber, to sterilize pharmaceuticals, preserve food, see through metal castings to spot flaws. In all these tasks, the amount of radiation must be measured and controlled to achieve the desired results.

Gage blocks, checked by NBS, are fundamental length measuring tools on American production lines.



Over the years, the Bureau has had many leaders in American science on its staff. Today, many of the Bureau's scientists are regarded as ranking authorities in their field.

About one-third of the professional staff hold Ph.D. degrees.

SUMMARY OF NBS STAFF / (As of June 30, 1966)

		WASHINGTON	BOULDER	TOTAL
	Total permanent staff	2,940	629	3,569
	Other staff*	335	106	441
	Total on rolls	3,275	735	4,010
	Research associates & guest workers	104	12	116
	TOTAL ON ROLLS AT NBS	**3,379**	**747**	**4,126**
Professional Staff**	Physicists	434	113	547
	Chemists	290	10	300
	Engineers	173	99	272
	Mathematicians	52	11	63
	Other	133	3	136
	TOTAL PROFESSIONAL STAFF	**1,082**	**236**	**1,318**

*WAE, consultants, students, teachers, postdoctoral fellows, and temporary-limited employees.
**Full-time permanent (excludes any under*).

The scope and variety of NBS work is almost impossible to convey in description alone. The following representative examples, drawn from the 1960's, will give a better view.

IN PHYSICS

Cesium beam frequency standard—A truly atomic standard for the atomic age, the cesium beam apparatus measures frequency and time in terms of cesium atom vibrations. NBS scientists are now able to measure time to one part in a trillion.

Photoelectric pyrometer—A photoelectric pyrometer—an instrument for measuring high temperature—was developed. It is more accurate than the standard visual pyrometer because it uses a photoelectronic system rather than the more fallible human eye.

Spectral data for space probes—NBS scientists measured the light-reflecting and absorbing properties of plants, animals, and minerals as a function of the wavelength of the light. The data will enable space probes to search for substances on other planets biochemically similar to life on earth.

Redetermination of atomic weights—The atomic weights of the elements silver, chlorine, bromine, and copper were rede-

termined by mass spectrometry. The values obtained for these elements are now accepted by the International Commission on Atomic Weights.

Improved value of the faraday—The faraday, the quantity of electricity transferred in electrolysis per gram equivalent of an element, was accurately redetermined. This electrical quantity is of major importance in physics and chemistry because it enters into the determination of other fundamental constants of matter.

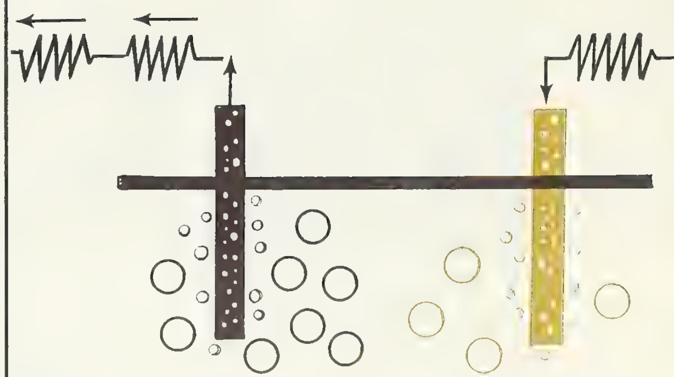
Acoustic thermometer—An acoustic thermometer developed at NBS was used to establish a new temperature scale and calibration service for the region 4-14°K.

Lasers in length measurement—As part of an investigation to determine the feasibility of using lasers as a wavelength source for accurate length measurement, interference fringes were obtained over a 200 meter path. Conventional light sources cannot produce interference fringes over distances of greater than 2 meters. Also, the laser was used to measure a one-meter length to an accuracy of better than one part in 10 million.

Exploring atomic structure—Two techniques—one utilizing the very-short-wavelength light from the NBS synchrotron, the other using electrons greatly accelerated but rigidly controlled so that they are made to travel at nearly identical speeds—were developed to learn more about the atomic nature of matter.

Superconducting semiconductor—NBS scientists observed what is believed to be the first example of superconductivity (loss of electrical resistance) in an oxide-type semiconductor.

Carbon-14 standard—The development of a new carbon-14 standard for liquid scintillation counters and the subsequent redetermination of the half-life of carbon-14 have enabled scientists to better utilize the carbon-14 method of dating archeological findings.



IN CHEMISTRY

Attaining absolute purity—A technique was developed which may someday provide scientists with absolute chemical purity. The technique involves continual removal of impurities from substances through a repeated heating-melting process.

pD scale—A new pH scale (called pD) for measuring acidity was developed for use with heavy water. Increasing use of heavy water, principally as a moderator and coolant for atomic reactors, raised the need for such a scale.

Aldehyde in air—A method was developed for measuring small amounts of aldehyde in the air. Analysis of the concentration of aldehydes in urban areas provides a good index of the amount of "smog".

Tungsten for high temperature coatings—Developed a method for plating high purity tungsten on metal surfaces such as rocket and missile nozzles and jet engine parts.

Standard metal-organic materials—A set of 24 standard samples of metal-organic compounds was developed for use in estimating the degree of engine wear by determining the amount of metals found in engine crankcase oils.

High purity crystals—An efficient, reproducible method for growing large single crystals from solution was developed. These crystals are homogeneous in structure and exceptionally pure.

Free radicals—NBS scientists made use of a frozen matrix isolation technique to conduct infrared studies of free radicals—chemical species which possess one or more unpaired electrons.

Coulometric titration—Developed an analytical method and a special coulometric-titration coulometer for the analysis and evaluation of chemical standards. Giving a precision of 10 parts per million, this technique is used to establish purity of chemical standards and reference materials.

Spectral line intensity tables—Prepared a tabulation of the relative intensities of 39,000 spectral lines, supplying spectrochemists with much needed information for the elements most commonly encountered in chemical analysis.

Standard reference material for Mossbauer spectroscopy—A standard reference material for Mossbauer spectroscopy was developed. Mossbauer spectroscopy has become an extremely valuable tool for determining the structural properties of materials and compounds.

IN ENGINEERING & INSTRUMENTATION

Measuring cooling loads of refrigerated trailers—A standard method was developed to aid in choosing adequate cooling machinery for refrigerated trucks.

Predicting transistor failure—An accelerated aging technique permits scientists and engineers to predict failure of various types of transistors even before they are placed in operation.

Corrosion protection—A study of the corrosion of ferrous pipelines resulted in the establishment of engineering guidelines for protection against corrosion by indicating the optimum electrical current that should be applied to the pipes.

Asphalt durability—A rapid, reproducible method was devised for predicting the durability of roofing asphalts by measuring the oxidation rate of the material.

Plumbing pipe size—To aid in choosing plumbing pipes of optimum size for vertical drains and vents, NBS developed a number of equations, tables, and charts to compute pipe dimensions and provide drains and vents ample but not excessive in size.

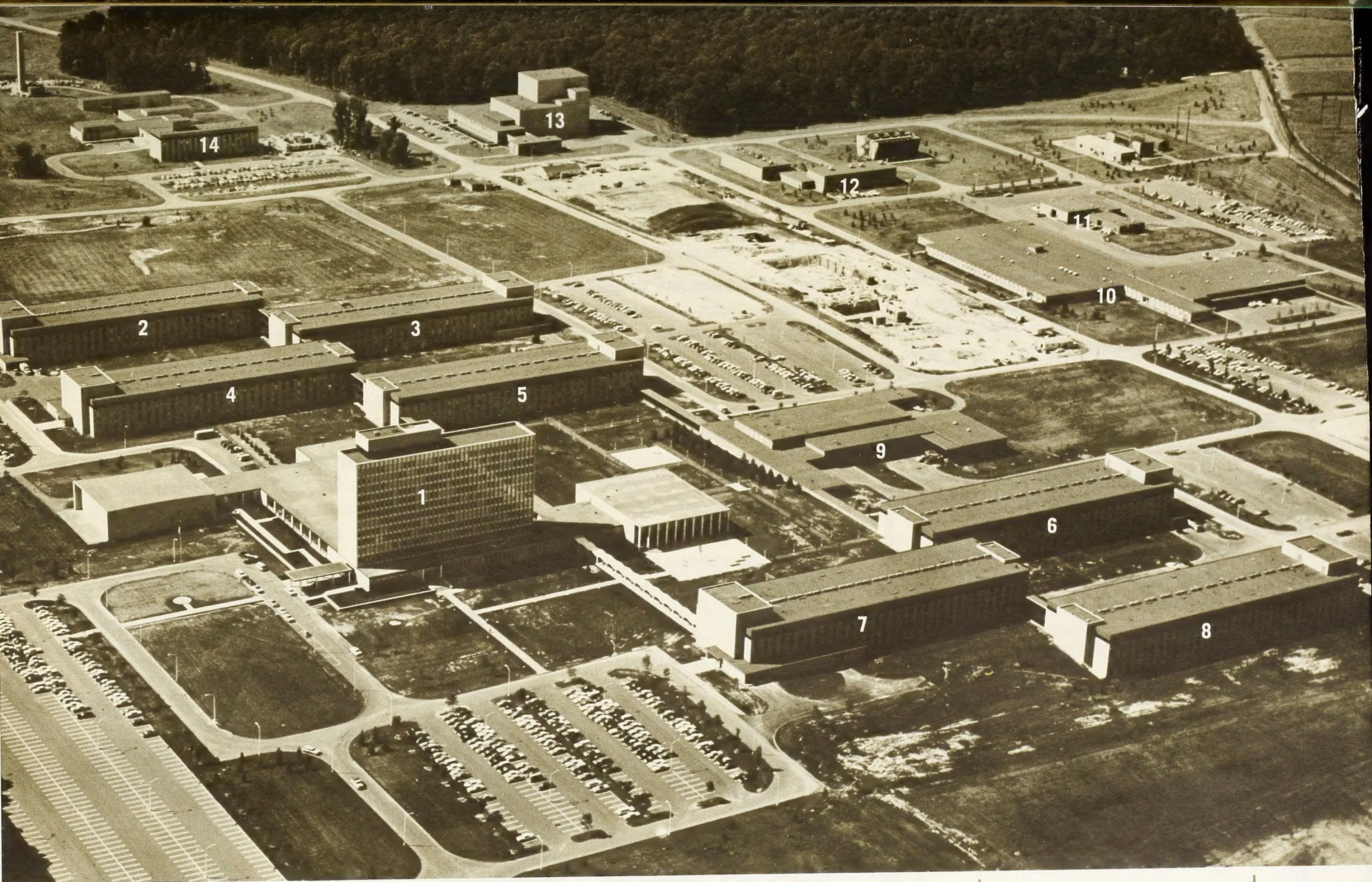
Project FIST—NBS engineers devised FIST (*F*ault *I*solation by *S*emi-Automatic *T*echniques), a very simple electronic troubleshooting system. The system makes possible routine maintenance of complex electronic equipment by personnel with little more than "bulb changing" training.

Redetermination of the ohm—The ohm—unit of electrical resistance—was redetermined by a new and more accurate method based on a capacitor whose value can be accurately determined from its physical dimensions.

Standard high-voltage resistor—Designed and built a shielded resistor for use in precise measurement of high voltages. It serves as a standard for calibrating other resistors.

IN MATHEMATICS

Handbook of mathematical functions—Prepared at NBS, this work brings together, for the first time under one cover, all of the special functions normally needed by anyone who uses mathematical tables in his work.



THE NATIONAL BUREAU OF STANDARDS, GAITHERSBURG, MARYLAND

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13. Engineering Mechanics
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15. Nuclear Reactor

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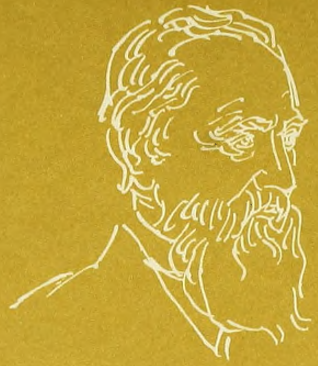
"It is therefore the unanimous opinion of your committee that no more essential aid could be given to manufacturing, commerce, the makers of scientific apparatus, the scientific work of the Government, of schools, colleges and universities than by the establishment of the institution proposed in this bill."

Report on Bill to establish
the National Bureau of Standards
House of Representatives –
May 14, 1900



"I often say that when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be."

Lord Kelvin—1883

U. S. DEPARTMENT OF COMMERCE
JOHN T. CONNOR, SECRETARY

J. HERBERT HOLLOMON,
ASSISTANT SECRETARY FOR
SCIENCE AND TECHNOLOGY

NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, DIRECTOR

November, 1966

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